

Design of Polarization Reconfigurable Microstrip Antenna with Frequency Tuning

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Abstract - This paper presents a polarization reconfigurable microstrip antenna with frequency tuning. Frequency reconfigurability is achieved by etching a rectangular ring slot in a corner truncated polarization reconfigurable antenna. Reconfigurability is achieved by electronic switching with the help of solid state device such as PIN diode. The proposed design is validated by simulation results. Return loss, axial ratio and gain characteristics of linear, right and left hand circular polarization states are presented at dual frequencies.

Index terms — frequency reconfigurable, microstrip antenna, PIN diodes, polarization reconfigurable, WLAN.

I. INTRODUCTION

In recent years reconfigurable antennas have been receiving much attention due to their several advantages. They reduce fading effects caused by multipath, increase the system capacity by frequency reuse, provide immunity to interfering signals, increase the communication link quality and reduce co-channel interference. They have more functionalities than conventional antennas and can be used in many wireless communication systems. The characteristics of the antenna that are reconfigurable are frequency, pattern, polarization or combinations of them.

Many designs reported [1]-[3] reconfigure only single characteristic of the antenna. Recently several antennas are designed to achieve combined reconfigurability [4][5]. Polarization and frequency reconfigurable antenna designed [6] has four pin diodes to achieve polarization agility and eight varactor diodes are employed for frequency tuning. A dual-polarized cavity-backed microstrip patch antenna with differential probe-feeds is presented [7] with independent frequency tuning. It uses varactor diodes and a matching circuit to achieve impedance match.

The combined reconfigurability can provide significant advantage over single reconfigurable design but the designer has to face greater challenges in designing polarization reconfigurable antennas with frequency tuning like (a) modeling of reconfiguration mechanism, (b) single antenna geometry operating with multiple modes has to be matched to the modes in all antenna configurations, (c) implementation of reconfigurable mechanism with control and bias circuits may

severely affect the performance of the antenna, (d) while optimizing the antenna for one parameter the other deviates. So, careful design and analysis is needed to reconfigure frequency and polarization independently.

This paper presents a polarization reconfigurable antenna with frequency tuning. It radiates linear polarization(LP), right hand circular polarization(RHCP) and left hand circular polarization(LHCP) at two frequencies using eight PIN diodes. The proposed antenna design is based on principle in [8] to achieve polarization reconfigurability. In this paper a rectangular ring slot is incorporated onto the patch to make the structure compact and to realize both frequency and polarization reconfigurability. The validity of the concept is demonstrated by simulation. Simulation results for return loss, axial ratio and radiation patterns are presented. Simulation is carried by Computer Simulation Technology (CST) Microwave Studio, a commercial EM simulator based on finite difference time domain method (FDTD) [9].

II. ANTENNA DESIGN

Polarization reconfigurable antenna switching between two WLAN bands is investigated. Fig.1 shows the geometry with all the dimensions in mm. It has a square patch of side 'S' printed on a RT Duroid substrate ($\epsilon_r = 2.2$, $\tan\delta = 0.0009$) with thickness 0.8mm and size 50mm $\times$ 50mm. Four parasitic triangular conductors are connected to corner truncated square microstrip antenna through PIN diodes (D_1 to D_4). A quarter wave line with dimensions $l_1 \times p$ is connected to a 50 Ω feed line with dimensions $l_2 \times w$ for impedance matching. A rectangular ring slot with inner dimensions $iw \times il$ and outer dimensions $ow \times ol$ is made inside the patch. Four PIN diodes (D_5 to D_8) are placed inside the ring slot. PIN diodes used in the proposed antenna are SMP1320-011F. According to datasheet of this diode, in 'ON' state it has 0.75 Ω resistance and in 'OFF' state it has 0.23pF capacitance. PIN diodes are modeled with these equivalent values in the simulation. Switches in general require a biasing network. The DC supply is provided to diodes D_1 to D_4 through inductor ($L=47nH$) connected to triangular conductors. The Central part of patch is etched to provide bias for diodes D_5 to D_8 . As shown in the inset the capacitor ($C=33pF$) maintains RF continuity, inductor L isolates RF and DC voltage. DC ground is achieved by using quarter wave transformer and a post.

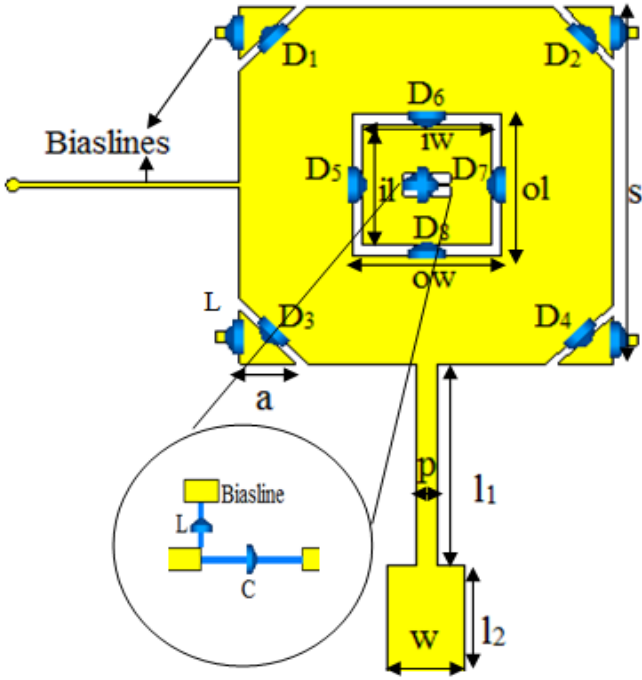


Fig.1. Geometry of the antenna. $S=15.16$, $l_1=8.42$, $l_2=9$, $p=0.8$, $w=3.9$, $a=1.31$, $ow=6.1$, $ol=6.7$, $iw=5.75$, $il=6.1$. (All linear dimensions in mm)

III. PRINCIPLE OF OPERATION

The microstrip antenna radiates linear polarization (LP) waves. For single feed microstrip antenna circular polarization (CP) can be generated by perturbing the antenna structure. With perturbation the fundamental mode is split into two orthogonal modes with slightly different frequencies. By aptly choosing the perturbations one CP resonant frequency can be found where the two modes TM_{10} and TM_{01} have same amplitude and 90° phase shift. In our design the corners of the patch are trimmed to obtain perturbation needed to generate CP. The antenna geometry can be altered to achieve either CP or LP using diodes. With diodes D1, D2, D3, D4 'ON' the geometry is symmetric generating LP. With D2, D4 'ON' and D1, D3 'OFF' RHCP is achieved. When D2, D4 is 'OFF' and D1, D3 is 'ON' LHCP is achieved. Four additional diodes used inside the rectangular ring achieve frequency tuning. By switching all the inner diodes D5, D6, D7 and D8 ON / OFF, the structure acts as the square antenna (A1) or rectangular slot ring antenna (A2) respectively.

With perturbation the fundamental resonant mode of square patch is split into two orthogonal modes with new frequencies f_a and f_b [10].

$$f_a = f_o \left(1 - 2 \frac{\Delta S}{S_1} \right) \quad (1)$$

$$f_b = f_o \quad (2)$$

Where ΔS is the total area of perturbations, f_o , S_1 are the resonant frequency and total area of the patch without perturbation. The resonant frequencies of both the modes decreases to f'_a and f'_b due to slot ring located on the square

patch. Eq. (1) and Eq. (2) are valid for A1, Eq. (3) and Eq. (4) are valid for A2.

$$f'_a = f_o \left(1 - 2 \frac{\Delta S}{S_1 - (ow \times ol)} \right) < f_a \quad (3)$$

$$f'_b = f_o = f_b \quad (4)$$

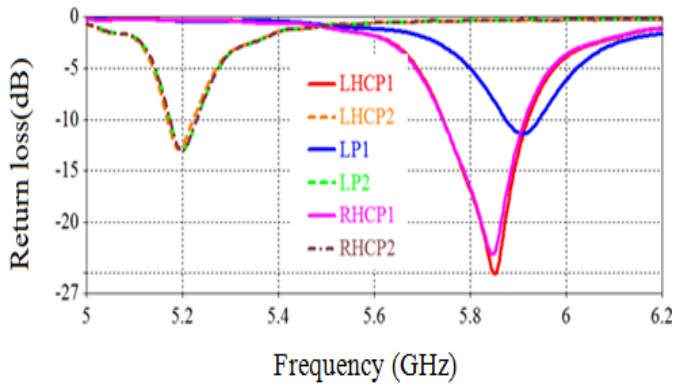
The CP and LP resonant frequency of A2 reduces due to increase in electrical length of the current. The frequency ratio can be controlled by properly choosing the dimensions of ring slot and perturbations.

IV. SIMULATION RESULTS

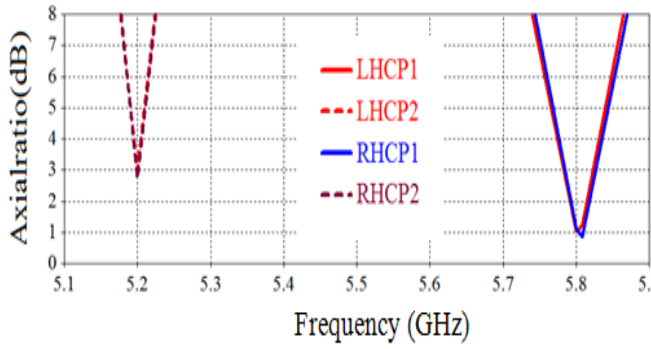
The simulated return loss and axial ratio plots for antenna A1 and A2 are shown in Fig.2. It can be observed from Fig. 2(a) that A1 resonates at 5.85GHz and A2 resonates at 5.2GHz. A1 in LHCP state has a return loss of -25dB at 5.85GHz with -10dB return loss bandwidth of 181MHz (3%) covering the frequencies lying between 5.74 to 5.92GHz. For RHCP return loss of -23dB is observed at 5.84GHz and the impedance bandwidth is same as LHCP. For LP return loss of -11.4dB is observed at 5.9GHz with -10dB return loss bandwidth of 73MHz (1.2%) covering the frequencies lying between 5.87 to 5.94GHz. For A2, a return loss of -13dB is observed for LHCP, RHCP and LP at 5.2GHz. The -10dB return loss bandwidth of 54MHz (1%) covering the frequencies lying between 5.17 to 5.22GHz is achieved. Impedance bandwidth of A2 is observed to be less compared to A1.

Fig. 2(b) shows the axial ratio characteristics for A1 and A2. For A1 the minimum axial ratio is 0.84dB at 5.8GHz; 3dB axial ratio is achieved over a frequency band 5.78 to 5.82GHz with a bandwidth of 45MHz. For A2, the minimum axial ratio is 2.7dB at 5.2GHz. A very less axial ratio bandwidth is observed. Axial ratio characteristics remain same in both the CP states. Fig. 3 shows the current distribution of the antenna A1 at 5.8GHz in RHCP state. It shows current variations at different instants of time. It is observed that the current rotates in anticlockwise direction as expected.

Fig.4 depicts simulated co-polar and cross-polar radiation patterns of antenna. It is observed from LP characteristics in Fig. 4(a) that co-polar radiation patterns E_ϕ and E_θ are similar. The cross-polarization is well below co-polar levels. Fig. 4(b) shows the co-polar and cross-polar radiation patterns in the principal planes for CP waves. The co-polar patterns are observed to be similar in both the planes. The cross-polar levels are observed to be below -17.8dB in both principal planes. The gain of the antenna A1 is observed to be 8.1dBi, 8.1dBic and 7.9dBic in LP, RHCP and LHCP states respectively. Fig. 5 depicts simulated co-polar and cross polar radiation patterns of antenna A2 in the principal planes. As observed from Fig.5 (a) the co-polar radiation patterns in the principal planes are almost same except that E plane beam is slightly broader than H plane pattern. Good cross-polar level is observed in E plane. In H plane it is below -20dB. Fig. 5(b) shows the co and cross polar radiation patterns in the principal planes for CP waves.



(a)



(b)

Fig. 2 Simulated results of A1 and A2 (a) Return loss (b) Axial ratio

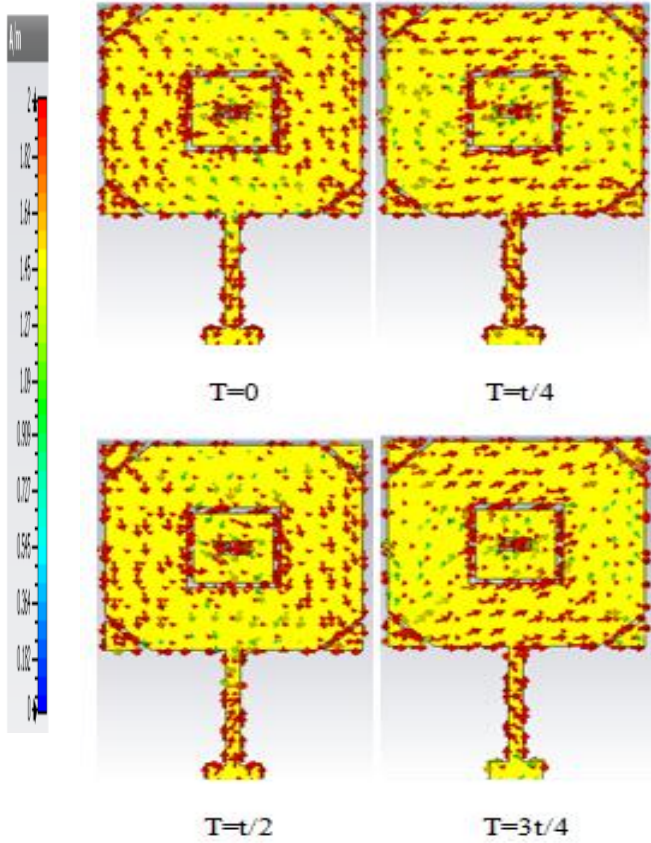


Fig. 3 Current distribution of A1 for RHCP state.

For RHCP the cross-polar level is -21dB and for it is -23dB in both the planes at bore sight. The simulated gain of the antenna A2 is observed to be 7.8dBi, 7.7dBic and 7.8dBic in LP, RHCP and LHCP states. It is observed that the axial ratio and gain characteristics of A2 is lower than A1 which suggests that square antenna has better radiation efficiency than ring slot square antenna. In A2, the reduction in gain is due to its reduced effective aperture area. The reduction in axial ratio is due to the compromise made to achieve frequency reconfigurability in addition to polarization reconfigurability.

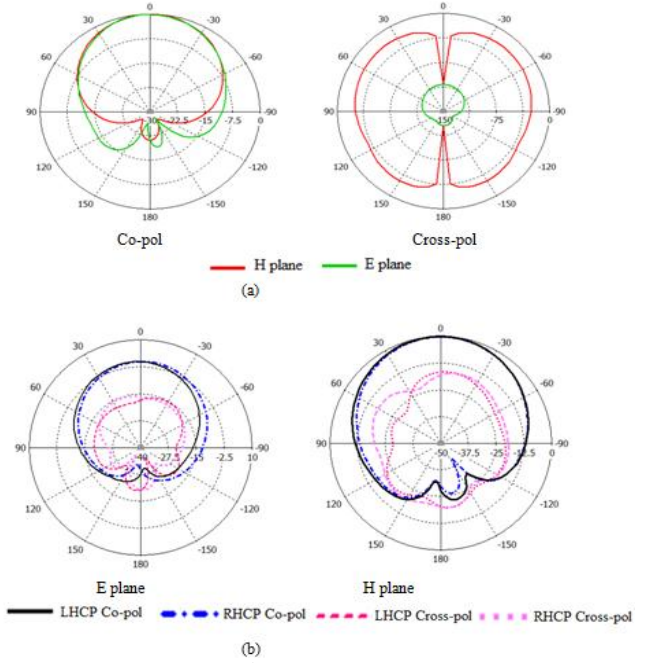


Fig. 4 Simulated radiation patterns of A1 (a) LP (b) CP

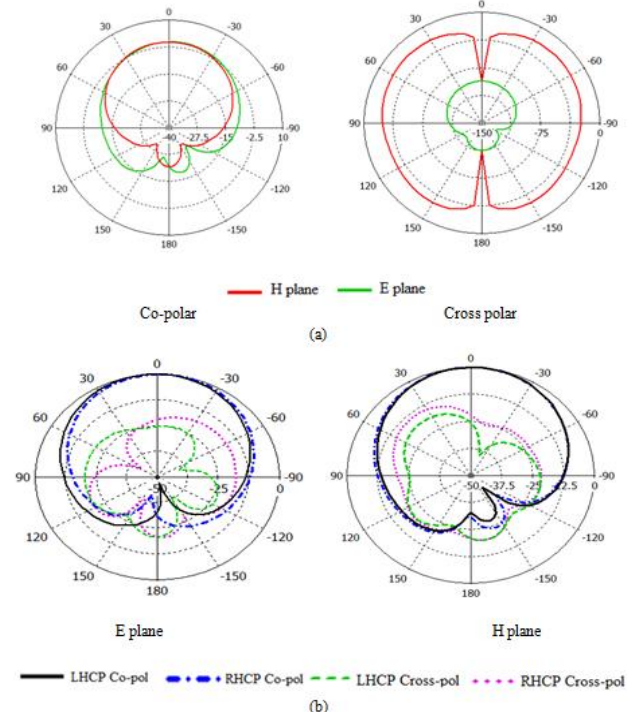


Fig. 5 Simulated co and cross polar radiation patterns of A2 (a) LP (b) CP

V. CONCLUSIONS

A frequency and polarization reconfigurable antenna is presented. A polarization reconfigurable antenna is designed initially to function at 5.8GHz. A rectangular ring slot is cut thereafter in the original patch to function at lower resonance of 5.2GHz. Pin diodes are placed at appropriate location in the ring slot to attain polarization reconfigurability at two different frequencies. The effect on the original patch due to the rectangular ring slot is examined by parametric analysis. The concept is validated by simulation results, which shows narrow band performance at dual frequencies 5.2GHz and 5.8GHz. The future work is targeted to experimentally verify the results by incorporating eight PIN diodes into the antenna configuration. Bandwidth could be further improved by using thicker substrate material. The proposed antenna can be used in WLAN Software defined radio or cognitive radio applications where both bands can be selected to function depending on the interference level. This is because both WLAN bands 5.8GHz and 5.2GHz have similar coverage due to their similar radiation characteristics.

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